Biological Warfare Defense Systems

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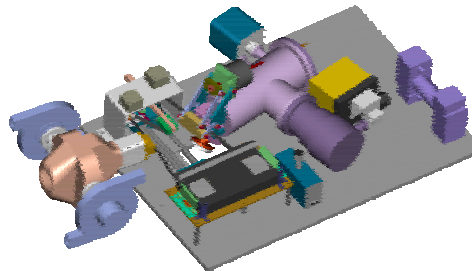
Chem/Bio Defense Activities
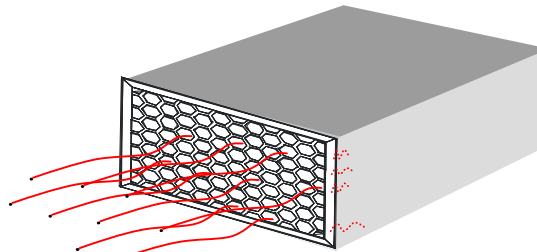
Component Technologies

– Detectors/ID
– Reporters
– Fluidics
– Collector materials
– Decon agents

Component Systems

Complete Defensive Systems

– Sensor systems

– Building Protection

– Filtration systems

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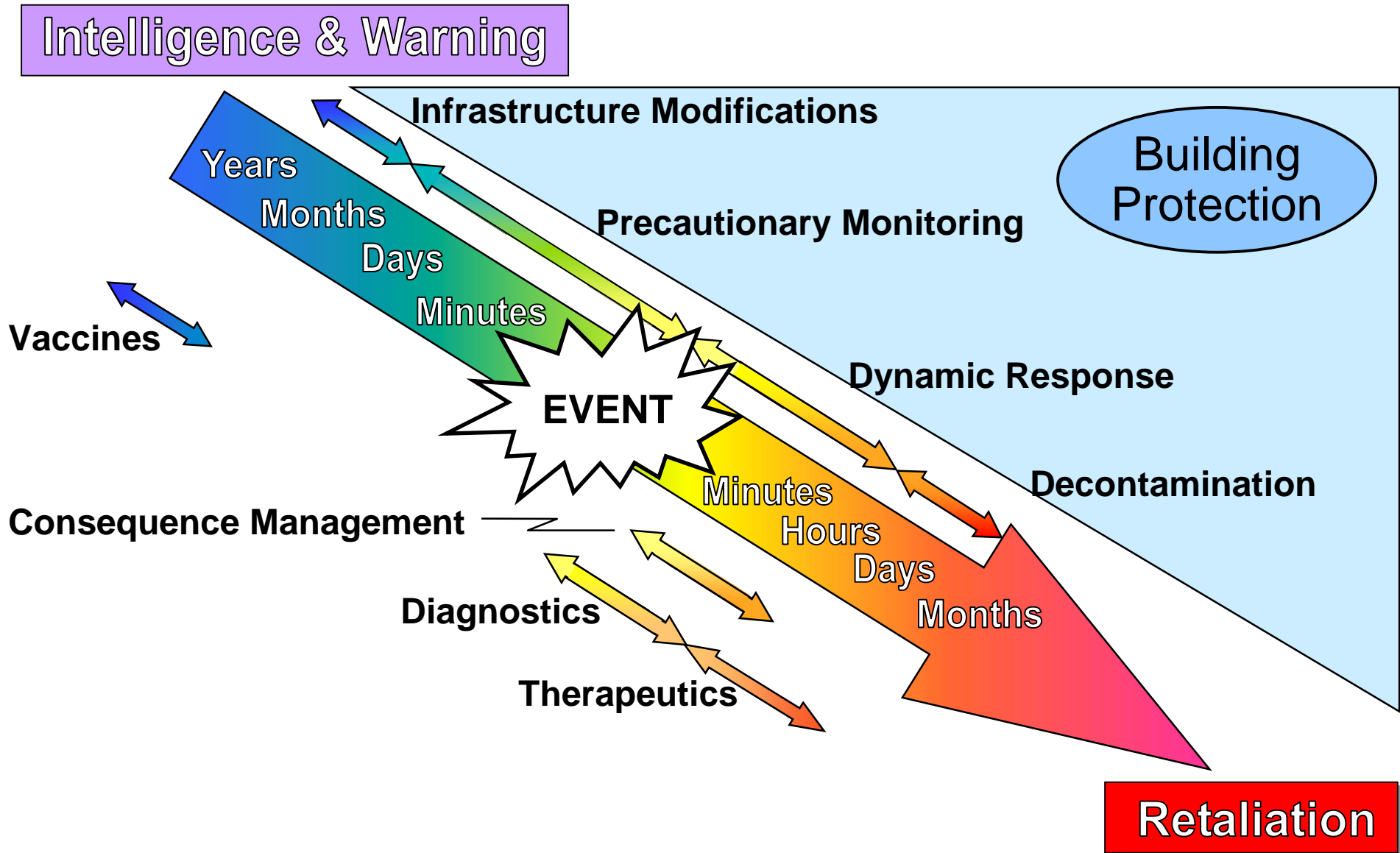
Threat:
- Focus is on protecting military buildings (C^2, barracks, …) from:
  - attack by chem or bio warfare agents;
  - external or internal release.

Goal:
- Make buildings far less attractive targets.

Approach:
- Reduce effectiveness of attack via dynamic response of HVAC (and other) infrastructure.

Objectives:
- Protect human inhabitants.
- Restore building to function, quickly.
- Preserve forensic evidence.

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- **Normal Operation**
  - Clean air continuously.
  - Increased biomass is suspicious.

- **Possible Attack**
  - Confirming sensors are slow.
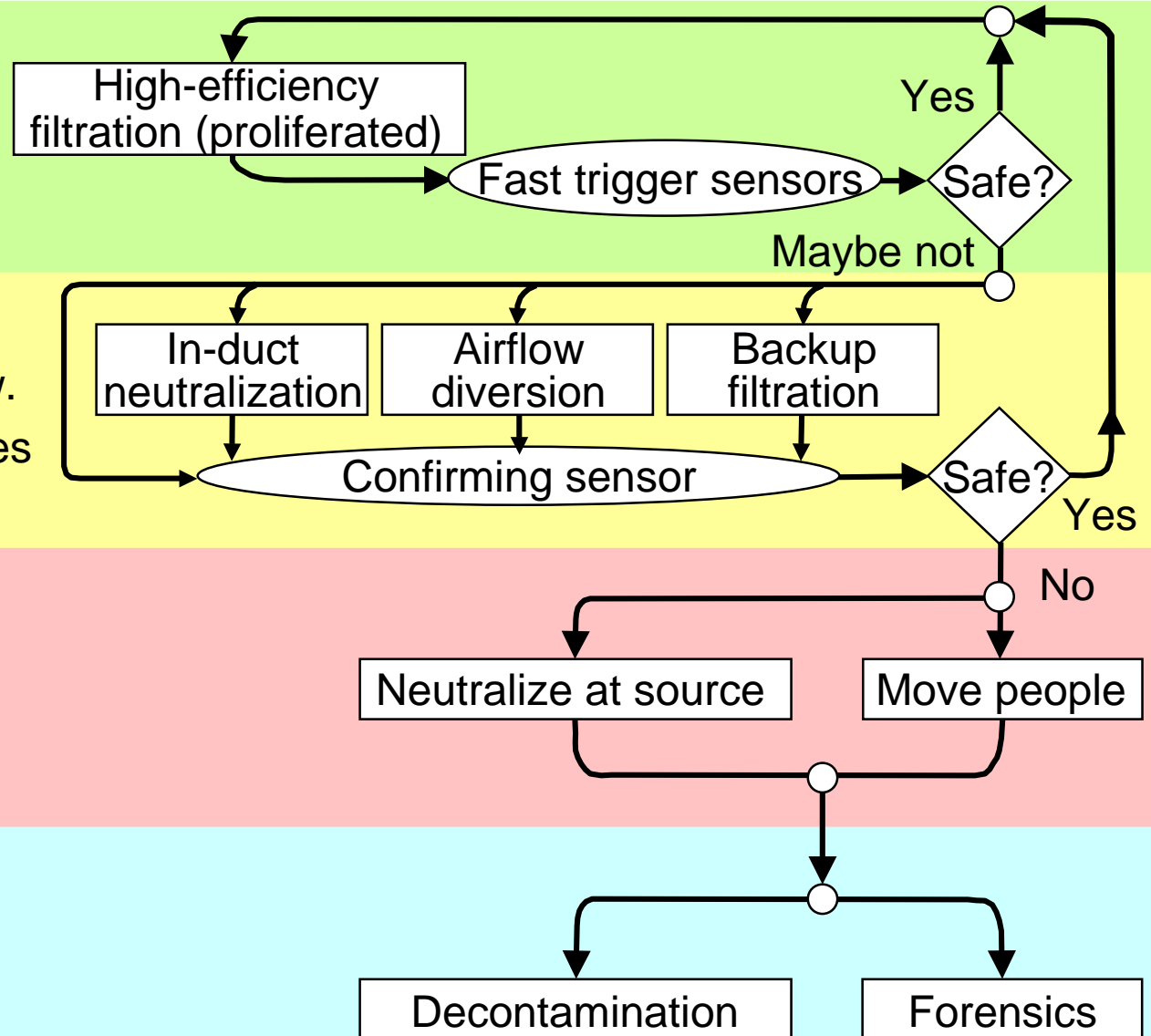 - Take precautionary measures in interim.

- **Confirmed Attack**
  - Full-scale response.

- **Post Event**
  - Clean up.
  - Attribution.

High-efficiency filtration (proliferated) → Fast trigger sensors → Safe?

Yes

Maybe not

In-duct neutralization | Airflow diversion | Backup filtration

Confirming sensor → Safe?

Yes

No

Neutralize at source | Move people

Decontamination | Forensics

- **Neutralization**
  - Efficient uv sources
  - Aerosol breakup
  - Photosensitizing agents
  - In-situ, toxic sprays
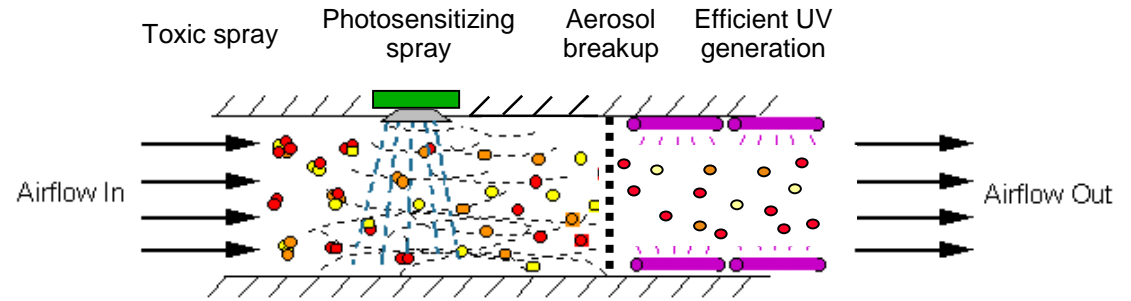
- **Filtration**
  - Low-Δp, high-efficiency filters
  - Combined chem/bio filters
  - Neutralizing filters
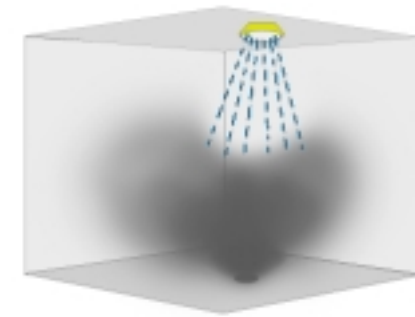
- **Decontamination**
  - Self-cleaning surfaces
  - Nano-bombs/emulsions

- **Sensors**

Toxic spray Photosensitizing spray Aerosol breakup Efficient UV generation

Airflow In   Airflow Out

Lethal agent   Ineffective agent

Catalyst
Wall

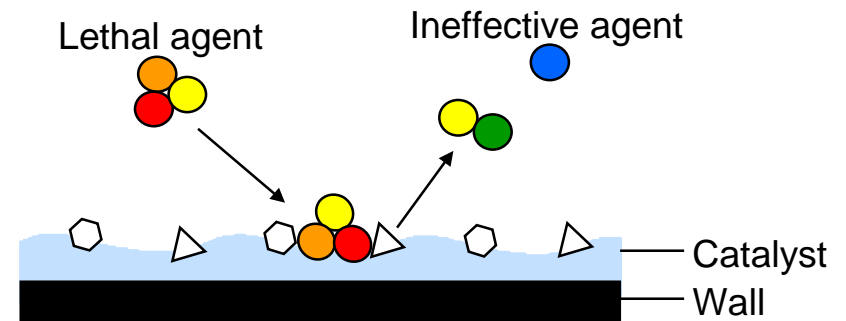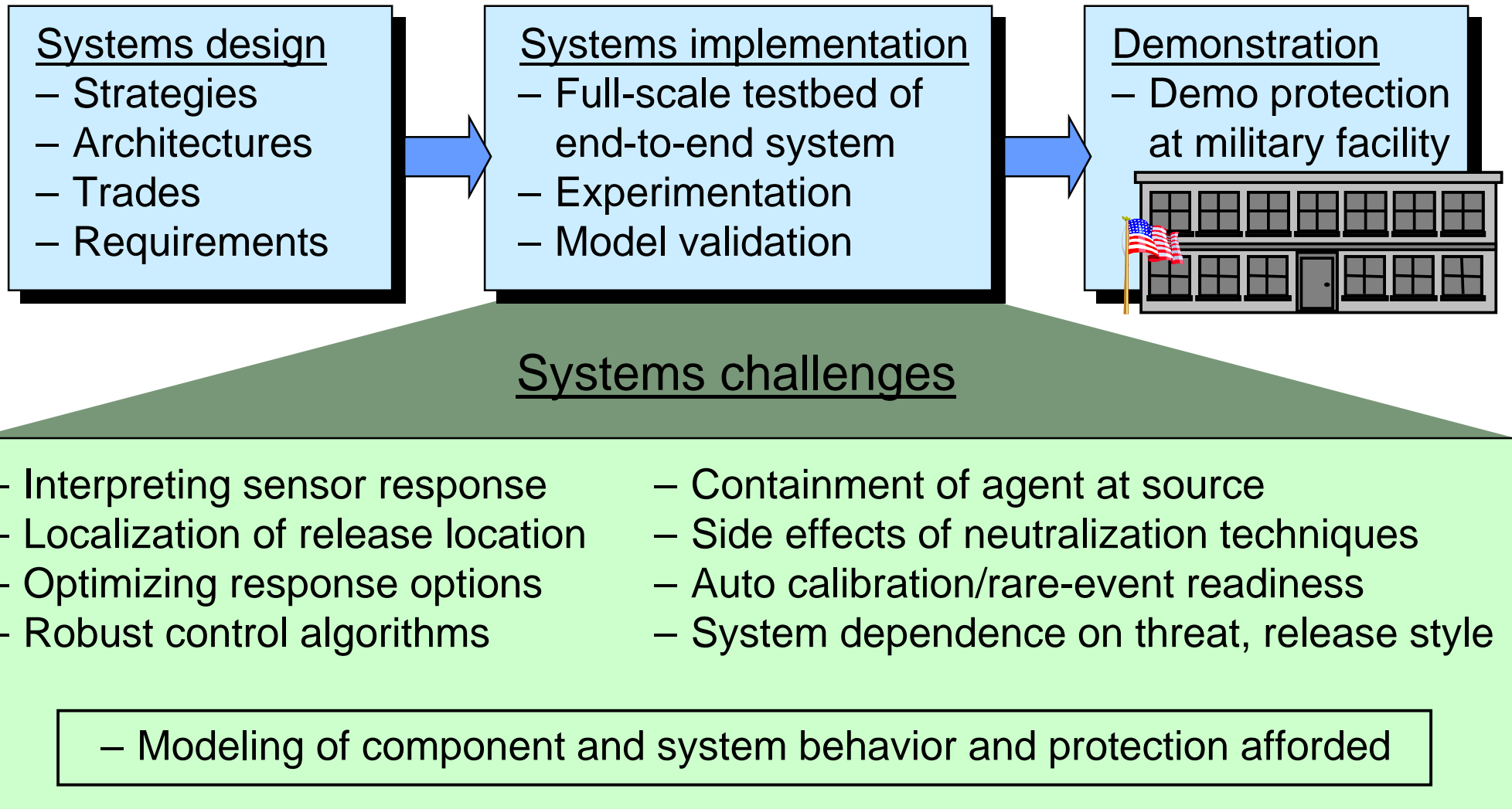# Integrated System Experimentation & Demo

Systems design
- Strategies
- Architectures
- Trades
- Requirements

Systems implementation
- Full-scale testbed of end-to-end system
- Experimentation
- Model validation

Demonstration
- Demo protection at military facility

Systems challenges

- Interpreting sensor response
- Localization of release location
- Optimizing response options
- Robust control algorithms

- Containment of agent at source
- Side effects of neutralization techniques
- Auto calibration/rare-event readiness
- System dependence on threat, release style

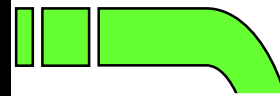- Modeling of component and system behavior and protection afforded

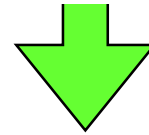# Building Protection Program Elements

FY01 – FY03

Technology Development
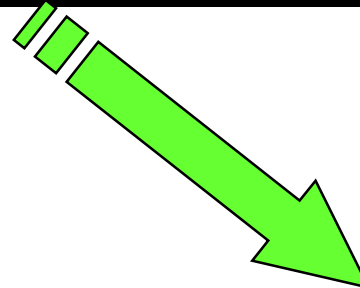– Chem components
– Bio components

Insertion opportunity

FY01 – FY04

Systems Experimentation
– Implement, test, optimize
– Measure system performance:
  FY01: external release
  FY03, FY04: internal release

FY04 – FY05

Demonstration
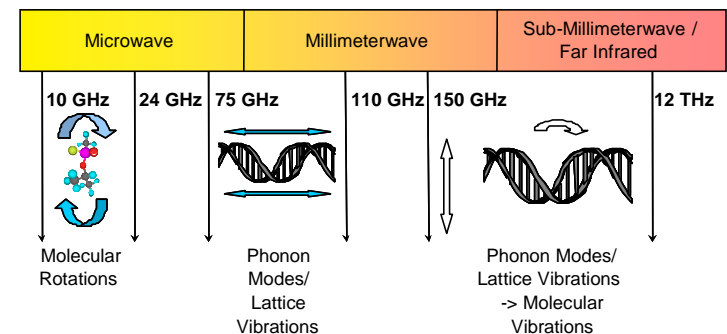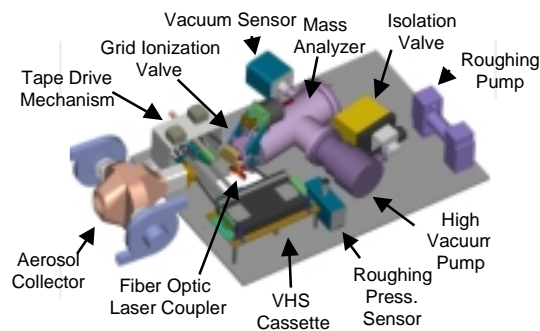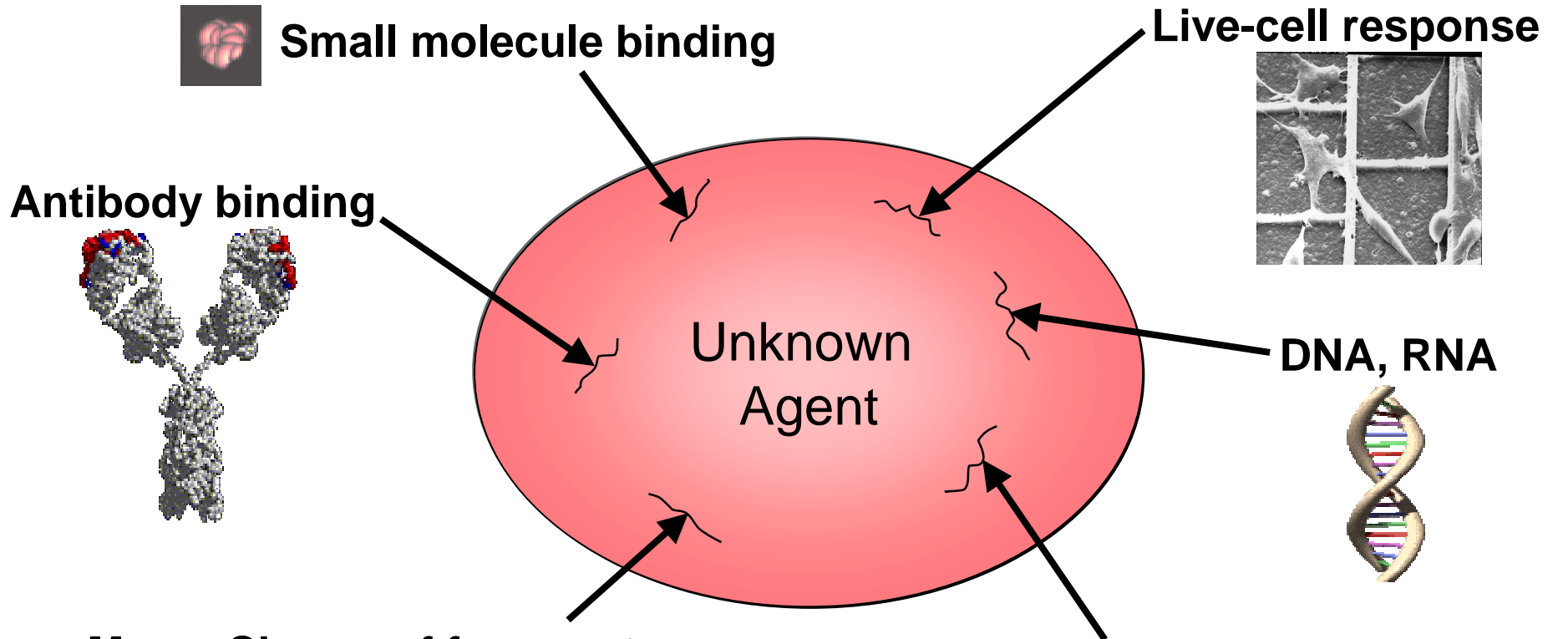– Military installation
– Based on experiments

- Bio sensors are a key component of many defensive architectures.

- Today's bio sensors do not perform well enough to enable their use in complex architectures.

- Fixing this shortcoming requires both novel sensor technologies and a change in how we design and develop sensor systems.

Small molecule binding

Live-cell response

Antibody binding

Unknown Agent

DNA, RNA

Mass: Charge of fragments

Tape Drive Mechanism
Grid Ionization Valve
Vacuum Sensor
Mass Analyzer
Isolation Valve
Roughing Pump
Aerosol Collector
Fiber Optic Laser Coupler
VHS Cassette
Roughing Press. Sensor
High Vacuum Pump

Resonances, energy transitions

Microwave	Millimeterwave	Sub-Millimeterwave / Far Infrared

10 GHz	24 GHz	75 GHz	110 GHz	150 GHz	12 THz

Molecular Rotations

Phonon Modes/ Lattice Vibrations

Phonon Modes/ Lattice Vibrations -> Molecular Vibrations

Induce chemical reactions

– Enzyme reaction

– Ca^{++} flow

– pH change

Light absorption/emission

– Of molecular labels (Fluorescent tags, UCPs)

– Of agent directly

Electron/ion flow

– Mass Spec

– Tissue sensors

Agent Identified

Mass loading/mechanical resonance

– SAW-like devices

– MEMS

Magnetic field

Components of (Bio) Sensors

Environmental Sample

Readout

Collect	Prepare	Identify	Report	Analyze
• High volume throughput	• Minimal prep / cleansing	• Sensitivity	• Strong reporting signal	• Unique / unambiguous result
• Collection of 1-10μ particles	• Speed	• Specificity	• Low background signal	• Simple algorithms
• High efficiency / low power	• Minimal consumables	• Speed	• Speed	• Robustness to interferents
		• Live vs dead, pathogenic vs non-deadly	• Multiplexed reporting	• Speed
		• Multiplexed ID	• High efficiency / low power	
		• Robustness to interferents		
		• Wide operating range (temp, himidity,…)		

Bio Sensor Systems

Environmental Sample

Readout

| Collect | → | Prepare | → | Identify | → | Report | → | Analyze |

Model (components & system)

- Model components and system.

- Optimize end-to-end performance.

- Understand limiting factors.

- Predict performance in new environments.

Characterize (sensitivity & specificity)

- Statistically significant P_D vs P_{fa}.

- Real environments (clutter, temperature, humidity…).

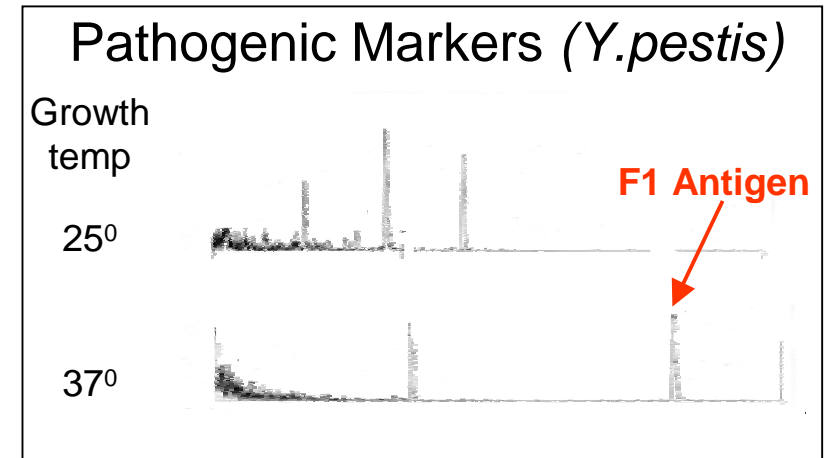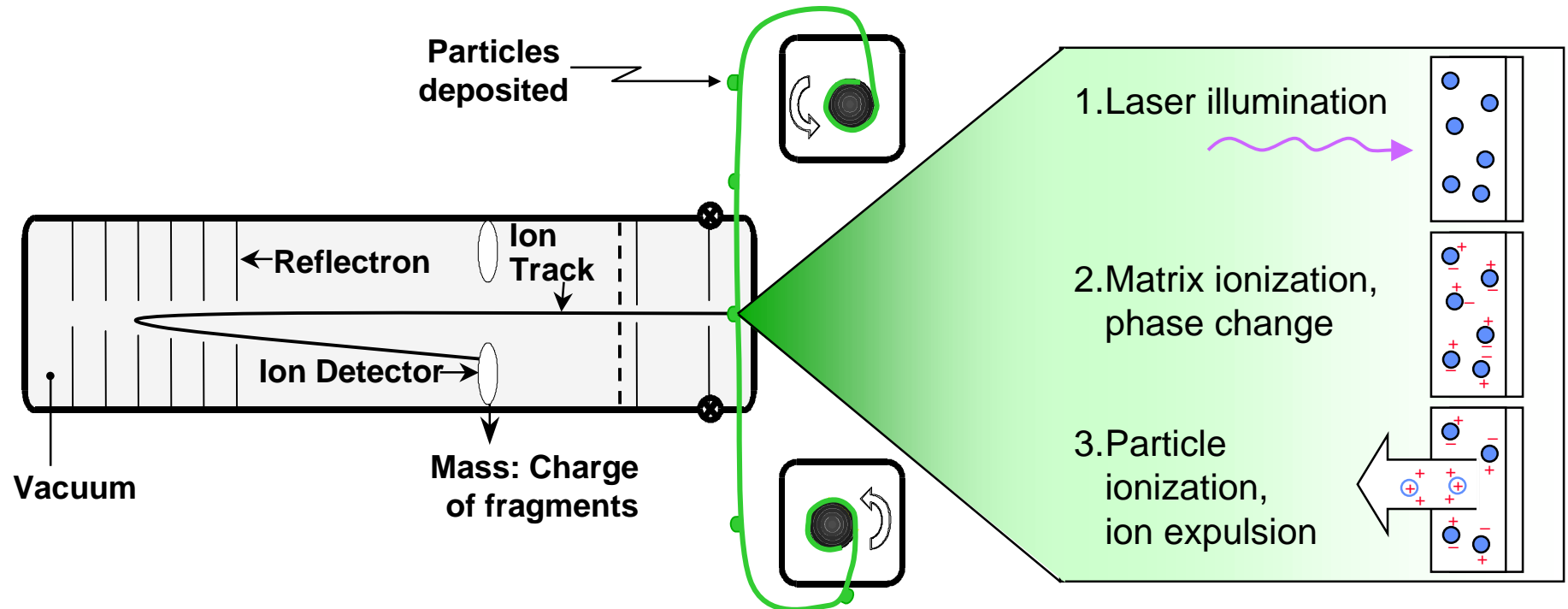- Operational protocols.

Mass Spec Prototype Development

Hardware proof of concept

- Technology components:
  - MALDI ionization
  - TOF reflectron
- Successfully generates spectra of whole proteins.

Pathogenic Markers *(Y.pestis)*

Growth temp

25^0

37^0

F1 Antigen

Systems Issues

- Agent signature library
- Stability of signature
- Instrument calibration
- Background signature characterization

- Signature quenching
- Algorithms for signature extraction
- Signature predictions
- Matrix modeling, optimization

Mass Spec Modeling

Particles deposited

Reflectron →

Ion Track

Ion Detector →

Mass: Charge of fragments

Vacuum

1. Laser illumination

2. Matrix ionization, phase change

3. Particle ionization, ion expulsion

- Ionization process plays important role in system sensitivity and variability.

- Modeling effort is underway to guide system optimization, interpretation of output.

SIMBAD

- Purpose: To develop and demonstrate prototype advanced sensor systems that work. They must be:
    - optimized;
    - well characterized;
    - reliable.

- Approach: New "way of doing business":
    - No stovepipes.
    - Broad technical expertise.
    - Strong systems-engineering lead.
    - End-to-end development.

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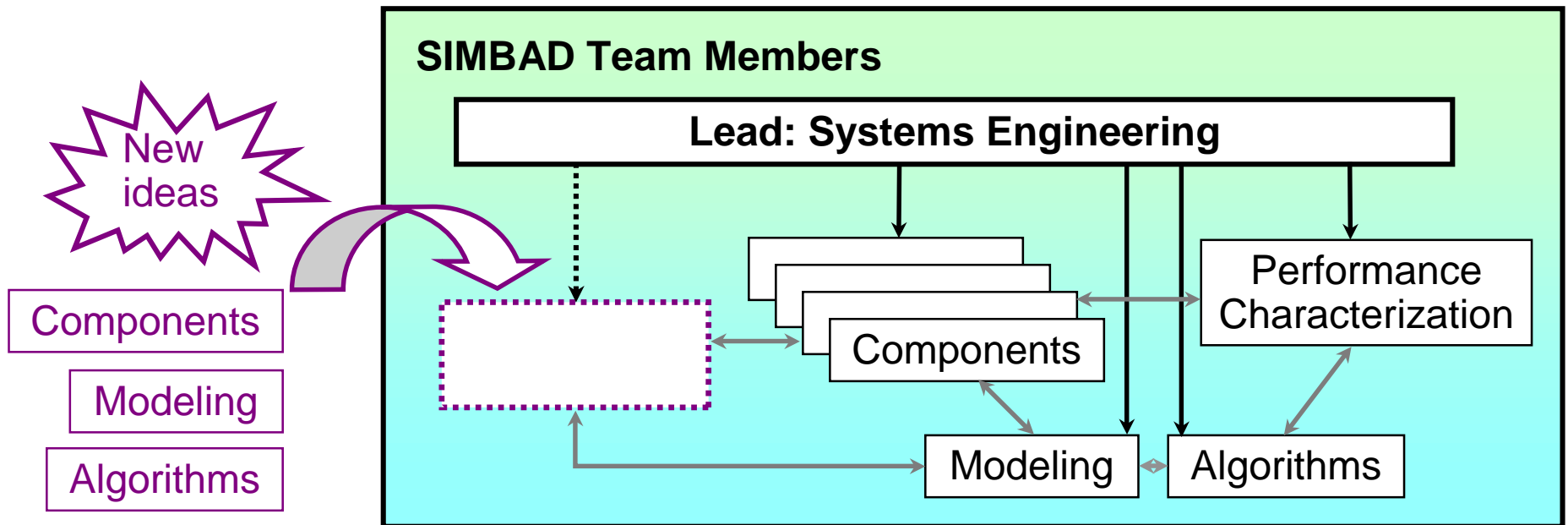
Contacts

- Office coordination   Amy E. Alving

- Building protection   tbd

- Sensors   Steve Buchsbaum, Millie Donlon

Other interests

- Bio surveillance systems

- Novel forensics

- Portal barriers for bio/chem

- Production detection